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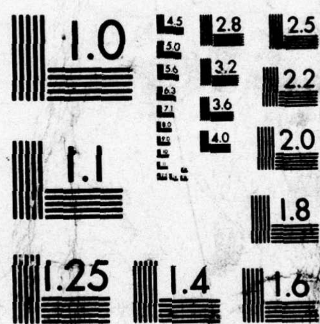
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EVALUATION OF SELECTED SAMPLES OF RETROREFLECTIVE MATERIAL FOR USE IN LASER TRACKING OF C3 AND C4 MISSILES

October 1976

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HEADQUARTERS AIR FORCE EASTERN TEST RANGE (AFSC)
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The objective of this report is to determine which type of reflective material, paint or tape, would be better to use on C3 and C4 missiles for laser tracking.

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EVALUATION OF SELECTED SAMPLES OF
RETROREFLECTIVE MATERIAL FOR USE IN
LASER TRACKING OF C3 AND C4 MISSILES

SUMMARY

Five samples of each of three retroreflecting materials were heat treated by Lockheed Missiles and Space Company. The samples represent various surface preparations used on the C3 and C4 missiles. Measurement of the luminance factor of the materials relative to a diffuse reflector, magnesium oxide, indicates that SCOTCHLITE #3870 is the most suitable of the three tested for enhancement of the C3 and C4 optical cross section. Measurements on SCOTCHLITE #7610, a high gain material, without heat treating indicate that it is even better and should be tested for durability under the heat loads expected.

1.0 INTRODUCTION

In order to enhance the optical cross section of missile targets for laser tracking it has been suggested that retroreflective tape or paint be applied to the missile surface (Ref 1). These materials would be a compromise between the unenhanced skin of the target and the corner cube retroreflectors that have proven highly effective in many laser tracking applications but which present operational problems to the missile test program. One of the serious concerns in considering the use of such material has been the question of how well they would stand up under the high temperatures experienced during launch. In response to requests for information on that subject, the Lockheed Missiles and Space Corporation (LMSC) treated three types of retroreflective material on each of five metallic substrates by subjecting the samples to a heat treatment similar to that which occurs on the missile surface. This report presents the results of reflectivity measurements on those samples.

1.1 Materials Tested

The three materials tested were labeled as follows:

A. SCOTCHLITE #7216 Paint,

B. SCOTCHLITE #3270 Tape - Silverwhite,

C. SCOTCHLITE #3870 Tape - Grey, Hex Pattern.

All three are 3-M Corporation products.

1.2 Substrate Test Panels (Ref 2)

Each material was applied to three test panels as follows:

1. 2024 Aluminum - no coating

2. 2024 Aluminum - MIL-P-2377 primer

   (This primer is used on the equipment sections of both the POSEIDON C3 and TRIDENT-1 C4 missiles.)

3. 2024 Aluminum - MIL-P-2377 primer plus MIL-C-83286 polyurethene top coat lightly sanded.

4. Same as 3 but not sanded.

5. 2024 Aluminum - WS3419 Epoxy polyumide primer plus MIL-C-22750 top coat.

   (The C3 equipment section finish coatings.)

1.3 Heat Treatment (Ref 2)

The samples, on 3-inch squares of aluminum, were placed in an oven at 440 degrees F (226 degrees C) which was heated to 480 degrees F (249 degrees C) over a 2-minute period. The cool-off period was not specified.

1.4 Visual Appearance of the Samples

Each of the materials, regardless of the surface treatment of the substrate, had approximately the same visual appearance changes. The appearance of material A, #7216 paint, remained unchanged. Material B, #3270 silverwhite, was covered with a plastic coating which bubbled. Some of the samples had large bubbles and some small ones. There was no noticeable discoloration. Similarly, the Material C, grey hexagonal pattern, was covered with a plastic material which was entirely removed from the surface leaving a rather sandy looking material.

1.5 Choice of Dependent Variable

The manufacturer, 3-M Company, characterizes its products such as the SCOTCHLITE brand reflective sheetings and paints by a luminance factor (LF). The luminance factor is the ratio of the brightness of the surface with the reflective sheeting or paint on it to the brightness of a perfectly diffuse (lambertian) surface. The manufacturer measures this quantity with a white light source. For present laser radar applications in the response at the ruby laser wavelength, .6943 μm, is of interest but for convenience of measurement a helium-neon laser at the .6328 μm wavelength was used. It was not verified that the response is the same at these two wavelengths but this assumption is commonly made for experimental convenience. The luminance factor was calculated from measurements of the laser light diffusely reflected from the sample material with the light reflected from a diffuse magnesium oxide (M_gO) block.

2.0 EXPERIMENTAL SETUP

The experimental setup for the luminance factor measurements is shown in Figure 1. The sample to be tested was mounted on an azimuth turntable and illuminated by a low power helium neon laser. The light was chopped at 23 Hz by a Princeton Applied Research Corporation (PARC) light chopper. The reflected light was detected by a model 9558 (S-20 photosurface) photomultiplier tube (PMT) through a 2-cm diameter aperture at a range of approximately 2-1/2 meters. The reference signal from the chopper and the signal from the PMT were sent to a PARC model 128 lock-in amplifier tuned to the chopping frequency. For convenience the detected voltage was read using a digital voltmeter. The transmitter and receiver were made coaxial by means of a pellicle beamsplitter.

The linearity of the phototube response was verified by measuring the response from the brightest of the samples and inserting calibrated neutral density filters between the laser and the beamsplitter. Figure 2 shows that this response is approximately linear over 3 decades of signal level.

3.0 RESULTS

Because this experiment was intended only to look for large variations in the diffuse reflectance of the samples no effort was made to apply statistical tests and only one replication was used. The only control on repeatability of data was that the instrumentation was allowed to stabilize for over an hour and occasional checks were made to insure that no large drifts had occurred. The repeatability of reference measurements appeared to be within about 10% and the variation was tentatively associated with uncertainty in the angular alignment of the samples.

3.1 The Effect of Heating

The ratio of the brightness measured for each treated material to the same material on the reference sample is given in Table 1.

TABLE 1

Ratio of LF of Each Material to that of Reference Sample of the Same Material

	MATERIAL		
Sample	A	B	C
1	1.08	.87	1.17
2	1.16	.93	1.11
3	1.51	.15	1.00
4	1.46	.09	1.10
5	1.19	.87	1.09

The luminance factor for the paint, material A, increased somewhat after heating. In samples 3 and 4 an increase of about 50% was seen.

Material C, the tape with the hexagonal pattern also showed an increase, probably because of the removal of the plastic coating which may have absorbed some of the light.

The LF of material B, the silverwhite tape, decreased for all samples. The amount of decrease could be correlated with the size of the bubbles in the plastic coating. This bubbling of the coating probably resulted from outgassing of the paint or sealer on the aluminum and was most pronounced in samples 3 and 4. Those two samples were treated with the polyurethane top coat under the SCOTCHLITE materials. The bubbles under the other samples were much smaller and the reflectivity was degraded less.

3.2 Angular Variation of LF

In addition to the relative comparisons of the treated samples with the reference sample, the LF of four samples with respect to a pressed M_gO block was measured versus angle of incidence. Results are shown in Figure 3. All three reference materials and one heat treated sample of material C were measured.

The results show that material C, SCOTCHLITE #3870, is by far the most reflective near normal incidence and even at rather large angles of incidence, out to 60 degrees, it is significantly higher than either of the other materials tested. This off-normal reflectivity is important for the laser tracking application because as the missile proceeds downrange the angle of incidence becomes large rather quickly.

3.3 A Possible Alternative Material

The 3-M Company makes a number of other SCOTCHLITE retroreflecting tapes in addition to those treated by LMSC. The 7600 series are called "high reflectivity" materials. The LF of a sample of SCOTCHLITE #7610 was measured with respect to the M_gO block for angles to 60 degrees incidence and obtained the results shown in Table 2. This material retains its retroreflecting quality at much higher incidence angles than the other materials tested.

TABLE 2

Luminance Factor vs Angle of Incidence for SCOTCHLITE #7610 at λ = .6328 μm

Angle of Incidence	0°	20°	40°	60°
Luminance Factor	248	287	400	361

A tentative heat resistance test was made on the SCOTCHLITE #7610. A strip of the tape was fixed to a small piece of scrap aluminum sheet and was heated to 200 degrees C for about 5 minutes. No visible change occurred. No attempt was made to duplicate the surface preparations used in the other samples and the oven used would not reach the temperatures of the LMSC test, so this thermal treatment can only be used as an indicator that this material merits further investigation.

4.0 CONCLUSIONS AND RECOMMENDATIONS

The measurements of luminance factor of the three materials heat treated by LMSC lead to the following conclusions:

1. SCOTCHLITE #3870 is the most suitable of the three materials to be used on the launch vehicles if one may assume that wind forces (q forces) will not further strip it off.

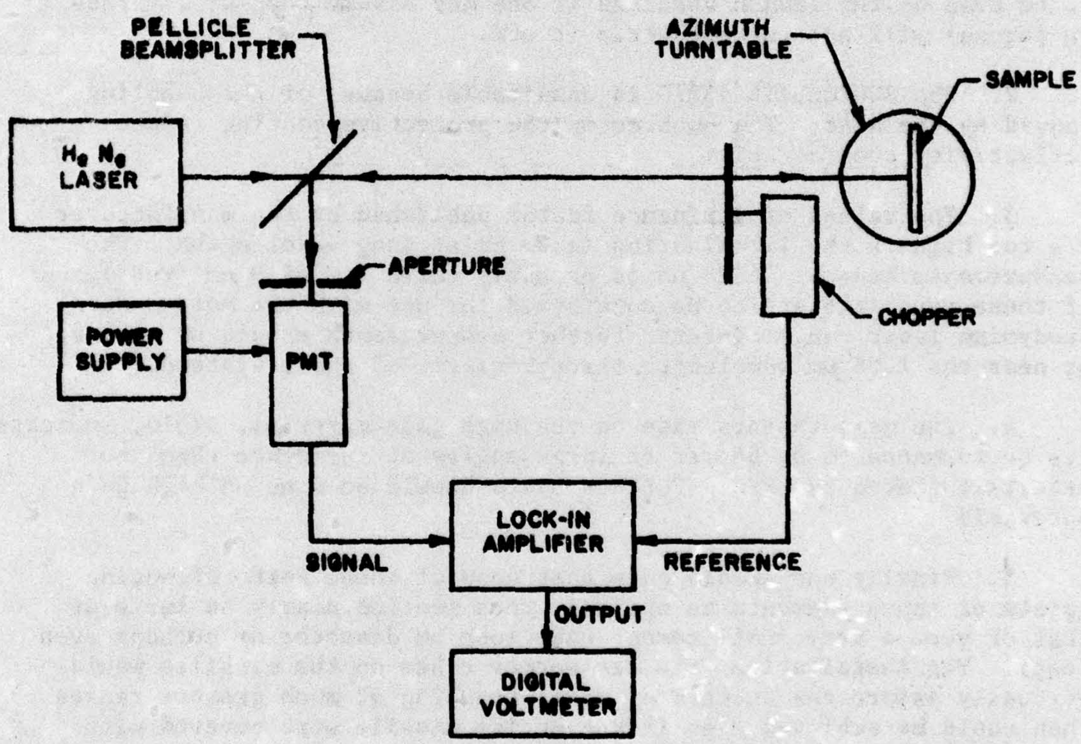
2. The SCOTCHLITE #3270 is unsuitable because of the bubbling caused by the heat. The bubbles in the protective coating reduce reflectivity considerably.

3. The values of luminance factor published by the manufacturer are too high if the illumination is to be at long wavelengths. The measurements made at .6328 μm is probably valid at .6943 μm (ruby), but if these materials are to be considered for use with the more modern neodymium laser range finders, further measurements should be made at or near the 1.06 μm wavelength characteristic of thor systems.

4. The measurements made on the high gain material, #7610, indicate its performance to be better at large angles of incidence than the materials tested by LMSC. Further tests should be done on high gain materials.

5. Finally one should note that none of these retroreflecting paints or tapes presents an optical cross section nearly as large as that of even a very small corner cube (one cm diameter or perhaps even less). The installation of a few corner cubes on the missiles would virtually assure the success of laser tracking at much greater ranges than could be achieved even if the entire missile were covered with the SCOTCHLITE materials.

Fig. 1. SETUP FOR SCOTCHLITE REFLECTIVE SURFACE MEASUREMENTS



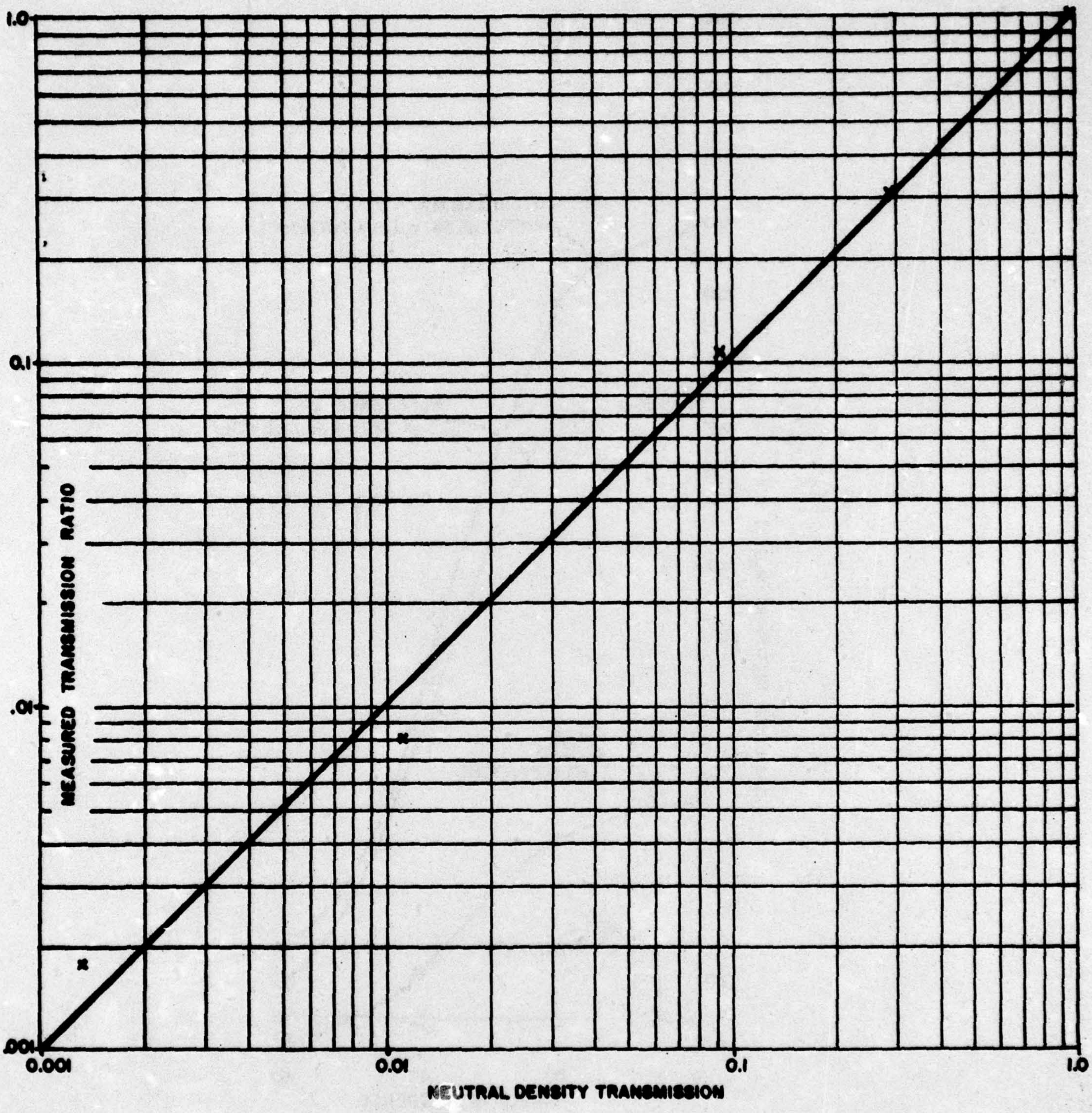


Fig. 2. PHOTOTUBE LINEARITY VERIFICATION SCOTCHLITE REFLECTIVE SURFACE MEASUREMENTS

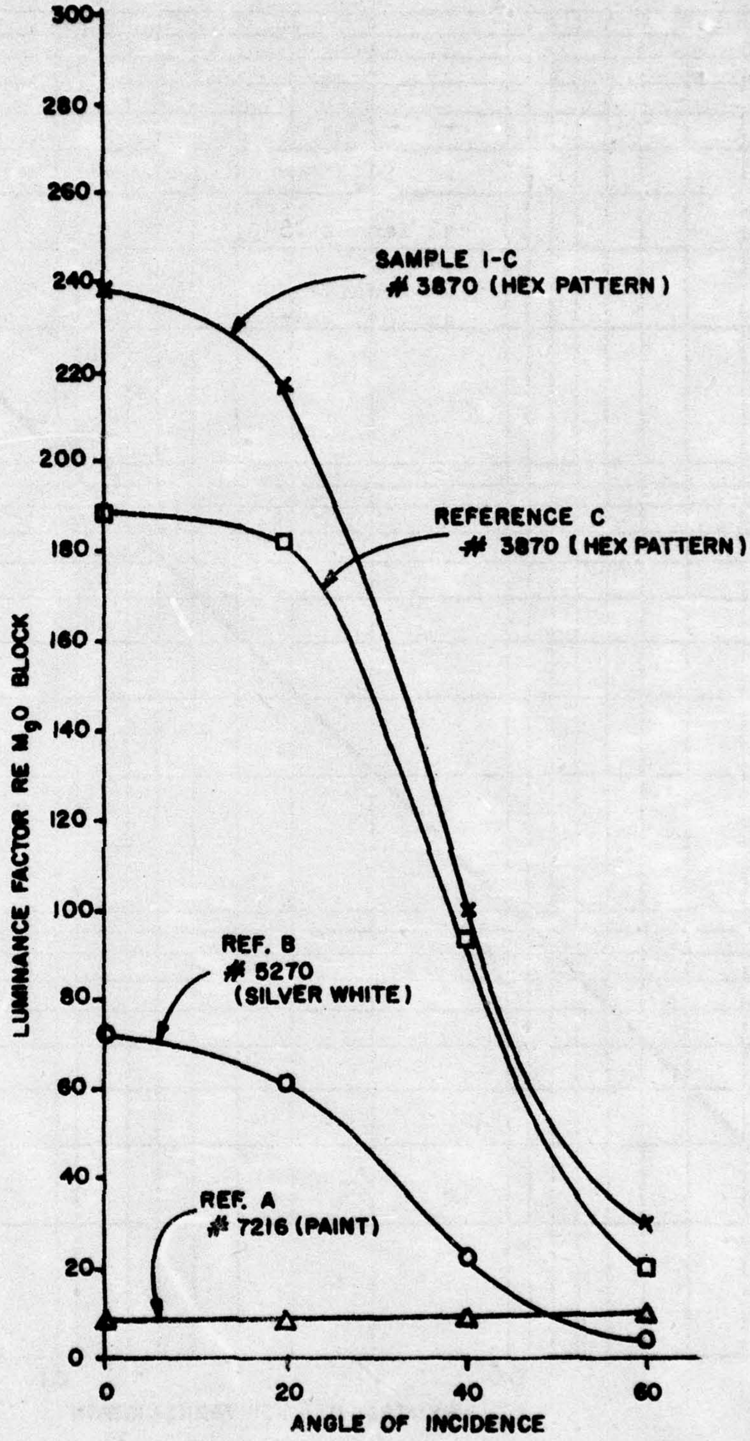


Fig. 3. SCOTCHLITE REFLECTIVE SURFACE MEASUREMENTS LUMINANCE FACTOR RELATIVE TO MgO BLOCK AT .6328 μm

REFERENCES

1. Mapes, S. N., Predicted S/N Performance of the RML/NASA Laser Ranger Against Cooperative Targets. Range Measurements Laboratory Technical Report 75-6, May 1975.

2. Description of Tests of Reflective Material for Use in Laser Tracking of C3 and C4 Missiles. Letter dated 24 August 1976 (LMSC-D513094)